



US011115154B2

(12) **United States Patent**
Li et al.

(10) **Patent No.:** **US 11,115,154 B2**
(45) **Date of Patent:** ***Sep. 7, 2021**

(54) **PROVIDING ACKNOWLEDGEMENT INFORMATION BY A WIRELESS DEVICE**

(58) **Field of Classification Search**
None
See application file for complete search history.

(71) Applicant: **Apple Inc.**, Cupertino, CA (US)

(72) Inventors: **Jun Li**, Richardson, TX (US); **Lai King Tee**, San Diego, CA (US)

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,931,569 B2 8/2005 Fong et al.
7,414,989 B2 8/2008 Kuchibhotla et al.
(Continued)

(73) Assignee: **Apple Inc.**, Cupertino, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

FOREIGN PATENT DOCUMENTS

KR 10-2007-0020027 2/2007
WO 2005119959 12/2005
WO 2008028006 3/2008

(21) Appl. No.: **16/705,005**

(22) Filed: **Dec. 5, 2019**

OTHER PUBLICATIONS

Office Action. Korean Patent Application No. 10-2011-7012377, dated Jul. 20, 2015. 17 pages.

(65) **Prior Publication Data**

US 2020/0119852 A1 Apr. 16, 2020

(Continued)

Related U.S. Application Data

(63) Continuation of application No. 15/914,472, filed on Mar. 7, 2018, now Pat. No. 10,530,532, which is a continuation of application No. 15/418,840, filed on Jan. 30, 2017, now Pat. No. 9,935,741, which is a continuation of application No. 14/883,800, filed on Oct. 15, 2015, now Pat. No. 9,571,233, which is a continuation of application No. 14/242,101, filed on (Continued)

Primary Examiner — Eunsook Choi

(74) *Attorney, Agent, or Firm* — Kowert, Hood, Munyon, Rankin & Goetzl, P.C.

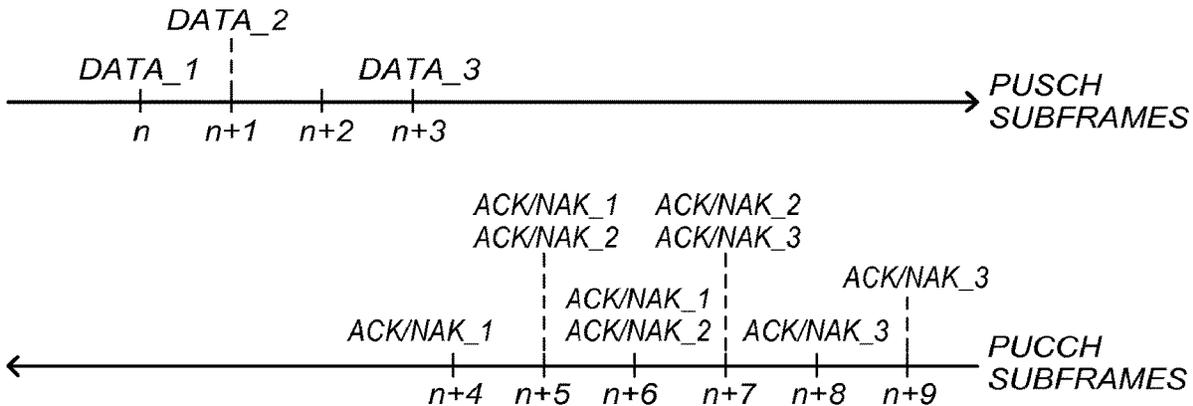
(57) **ABSTRACT**

In general, to provide acknowledgment information by a first wireless device, the first wireless device sends repeated instances of acknowledgment information in respective first and second frame structures, in response to receipt of first information from a second wireless device. In addition, the first wireless device also sends further acknowledgment information in the second frame structure that is responsive to second information received from the second wireless device.

(51) **Int. Cl.**
H04L 1/16 (2006.01)
H04W 72/04 (2009.01)
H04L 1/18 (2006.01)
H04W 28/04 (2009.01)

(52) **U.S. Cl.**
CPC **H04L 1/1635** (2013.01); **H04L 1/1858** (2013.01); **H04W 72/0406** (2013.01); **H04W 28/04** (2013.01)

21 Claims, 3 Drawing Sheets



Related U.S. Application Data

Apr. 1, 2014, now Pat. No. 9,191,161, which is a continuation of application No. 13/124,617, filed as application No. PCT/US2009/063264 on Nov. 4, 2009, now Pat. No. 9,083,522.

(60) Provisional application No. 61/111,126, filed on Nov. 4, 2008.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,898,244	B2	3/2011	Taylor et al.	
8,432,875	B2	4/2013	Dai et al.	
9,571,233	B2	2/2017	Li et al.	
2002/0168945	A1	11/2002	Hwang et al.	
2007/0024559	A1	2/2007	Ahu et al.	
2007/0162810	A1	7/2007	Sato et al.	
2007/0254662	A1*	11/2007	Khan	H04L 1/1825 455/436
2007/0286146	A1	12/2007	Kuroda et al.	
2008/0095109	A1*	4/2008	Malladi	H04L 1/1858 370/330
2008/0209301	A1	8/2008	Chang et al.	
2009/0046649	A1*	2/2009	Gao	H04L 1/1861 370/329
2009/0055703	A1*	2/2009	Kim	H04W 72/044 714/748
2009/0110038	A1*	4/2009	Montejo	H04L 5/0053 375/211
2009/0129317	A1*	5/2009	Che	H04L 1/1829 370/328
2009/0207793	A1*	8/2009	Shen	H04L 5/0094 370/329
2009/0213769	A1*	8/2009	Shen	H04L 1/1858 370/280
2011/0002309	A1*	1/2011	Park	H04L 1/1607 370/335
2011/0164662	A1*	7/2011	Kishiyama	H04L 1/1858 375/219
2011/0206018	A1*	8/2011	Li	H04L 1/1635 370/336
2012/0201327	A1*	8/2012	Kim	H04L 1/1812 375/295
2014/0016522	A1*	1/2014	Ahn	H04L 5/0055 370/280

OTHER PUBLICATIONS

LGE, Nokia, NSN, Panasonic, Ericsson, TI and Samsung, Correction of PUCCH index generation formula [online], 3GPP TSG-RAN WG1#53b RI-082715, Internet <URL: http://www.3gpp.org/fltpsg_ran/WG1_RL_1/SGR1_53b/Docs/R1082715.zip>, Jul. 2008 (pre-

senting well-known technique), (Note) Due to Legal or contractual restrictions, etc., a part or all of the presented Non-Patent Documents may not be served.

Office Action, Japan Application No. 2014-184206, dated Jun. 29, 2015, 6 pages.

Office Action from Canadian Application No. 2742800, dated Dec. 23, 2014, pp. 1-5.

Office Action from Japanese Patent Application No. 2011-534899, dated Oct. 24, 2013. (English and Japanese Versions), pp. 1-11.

Texas Instruments, ACKINAK Repetition in EUTRA Uplink [online], 3GPP, TSG-RAN WG1#53 RI-081981, Internet <URL: http://www.3gpp.org/ftp/tsg_ran/WG1_RL_1/TSGR1_53/Docs/RI-081981.zip>, May 5-9, 2008, pp. 1-2.

Motorola, Uplink ACKINACK Repetition [online], 3GPP TSG-RAN WG1#53b RI-082474, Internet <URL: http://www.3gpp.org/ftp/tsg_ran/WG1_RL_1/TSGR1_53b/Docs/RI-082474.zip>, Jun. 29-Jul. 4, 2011, pp. 1-4.

Texas Instruments, Nokia Siemens Networks, Nokia, LGE, Samsung, ZTE, Way forward on support of ACKINAK repetition [online], 3GPP TSG-RAN WG1#53b RI-082739, Internet <URL: http://www.3gpp.org/ftp/tsg_ran/WG1_RL_1/TSGR1_53b/Docs/RI-082739.zip>, Jun. 30-Jul. 4, 2011, pp. 1-4.

First Office Action and translation thereof in Chinese Patent Application No. 200980144239.3, dated May 6, 2013, pp. 1-13.

International Search Report and Written Opinion dated Jun. 11, 2010 for International Application No. PCT/US2009/063264, International Filing Date: Nov. 4, 2009 consisting of 10-pages.

U.S. Appl. No. 61/111,126, filed Apr. 15, 2011, Jun Li.

Notice of Allowance, Korean Patent Application No. 10-2011-70123 77, dated Jan. 28, 2016, 7 pages.

Office Action, Japanese Application No. 2014-184206, dated Dec. 28, 2015, 6 pages.

Texas Instruments, ACKINAK Repetition in EUTRA Uplink [online], 3GPP, TSG-RAN WG1#53 RI-081981, Internet <URL: http://www.3gpp.org/ftp/tsg_ran/WG1_RL/TSGR1_53/Docs/RI-081981.zip>, May 5-9, 2008, pp. 1-2.

Motorola, Uplink ACKINACK Repetition [online], 3GPP TSG-RAN WG1 #53b RI-082474, Internet <URL: http://www.3gpp.org/ftp/tsg_ran/WG1_RL_1/TSGR1_53b/Doc/RI-082474.zip>, Jun. 29-Jul. 4, 2011, pp. 1-4.

3GPP TSG RAN WG1 #54bis; RI-083527; Way Forward on Support of ACK/NAK Repetition; Prague, Czech Republic, Sep. 29-Oct. 3, 2008; Texas Instruments, LGE, Samsung, ZTE; pp. 14.

3GPP TSG RAN WG1 #54bis; RI-084046; Way Forward on Support of ACK/NAK Repetition; Prague, Czech Republic, Sep. 29-Oct. 3, 2008; Texas Instruments, LGE, Samsung, Motorola., ZTE, NTT DoCoMo, RIM, CMCC, CAT; pp. 1-4.

Office Action for Indian Patent Application No. 2622/CHENP/2011, dated Aug. 22, 2017, pp. 1-6.

Office Action for Chinese Patent Application No. 201410482348.9, dated Mar. 28, 2017, pp. 1-8.

* cited by examiner

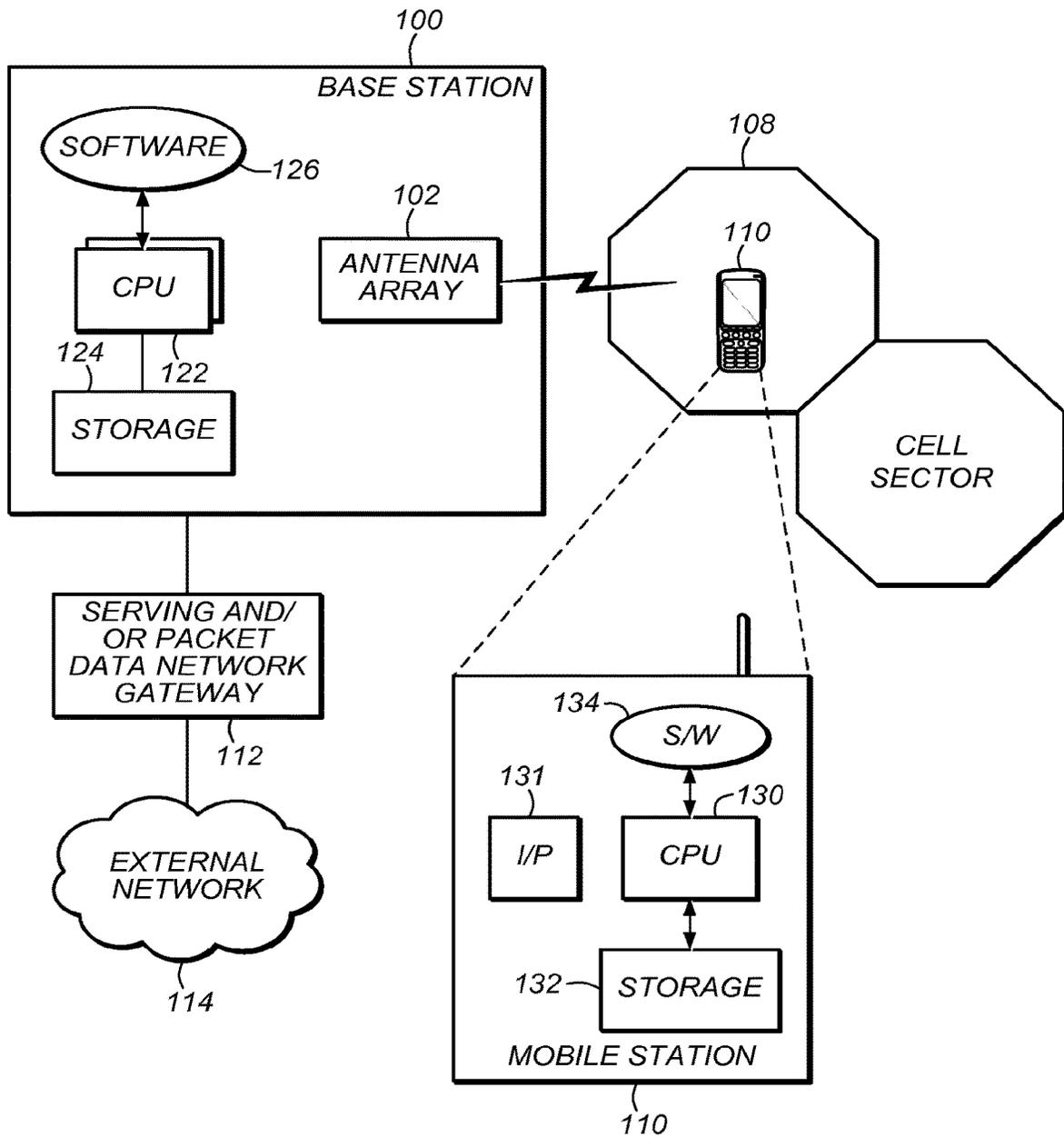


FIG. 1

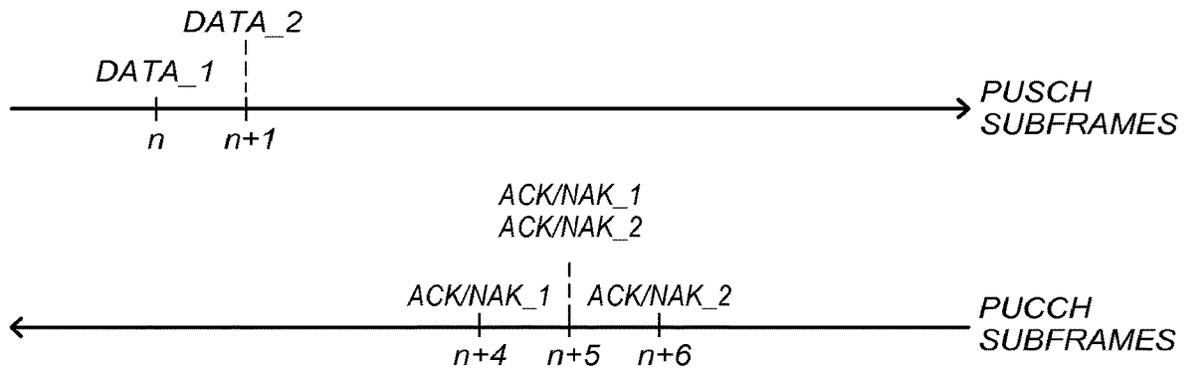


FIG. 2

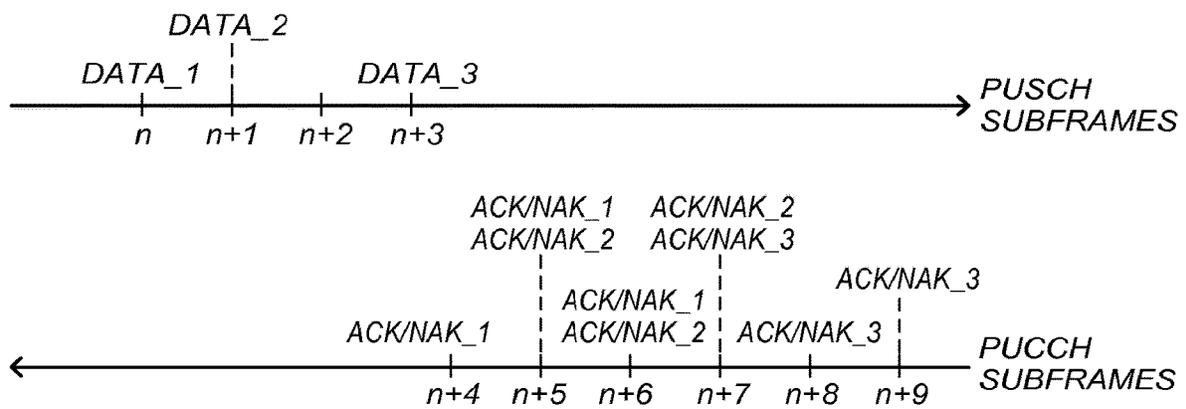


FIG. 3

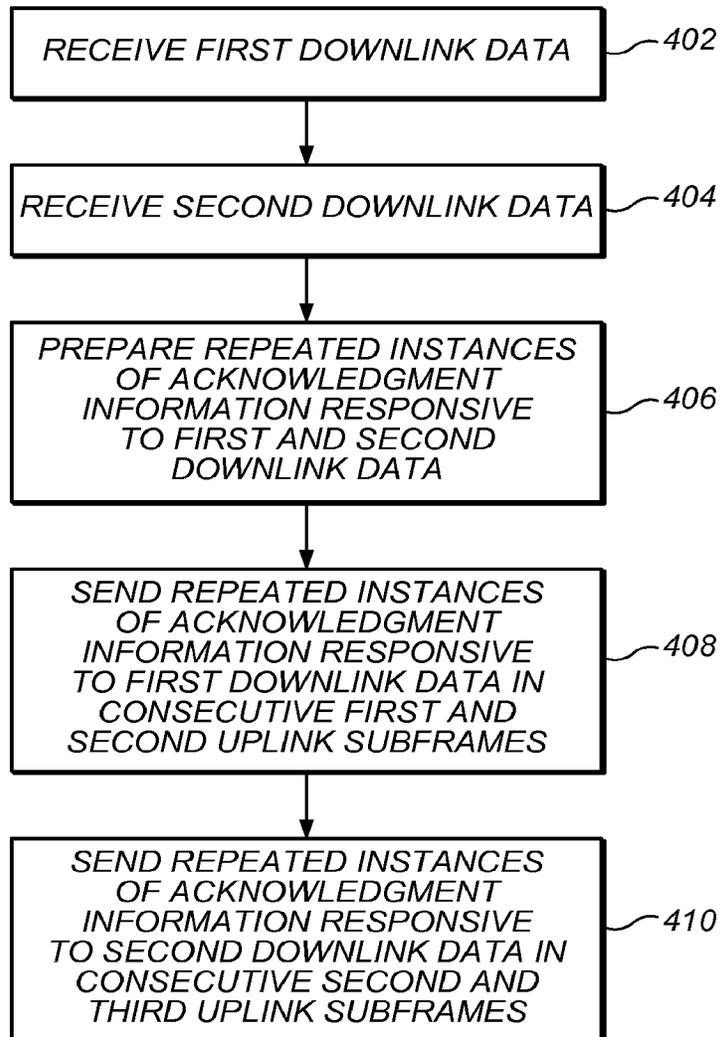


FIG. 4

**PROVIDING ACKNOWLEDGEMENT
INFORMATION BY A WIRELESS DEVICE**

CROSS-REFERENCE TO RELATED
APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 15/914,472, filed Mar. 7, 2018, entitled "PROVIDING ACKNOWLEDGEMENT INFORMATION BY A WIRELESS DEVICE", which is a continuation of U.S. patent application Ser. No. 15/418,840, filed Jan. 30, 2017, which is a continuation of U.S. application Ser. No. 14/883,800, filed Oct. 15, 2015, of the same title, now U.S. Pat. No. 9,571,233, which is a continuation of U.S. patent application Ser. No. 14/242,101, filed Apr. 1, 2014, of the same title, now U.S. Pat. No. 9,191,161, which is a continuation of U.S. patent application Ser. No. 13/124,617, filed Apr. 15, 2011, of the same title, now U.S. Pat. No. 9,083,522, which is a Submission Under 35 U.S.C. § 371 for U.S. National Stage Patent Application of International Application No. PCT/US2009/063264, filed Nov. 4, 2009, of the same title, which claims priority to U.S. Provisional Application No. 61/111,126, filed Nov. 4, 2008, the entirety of which are incorporated herein by reference.

The claims in the instant application are different than those of the parent application or other related applications. The Applicant therefore rescinds any disclaimer of claim scope made in the parent application or any predecessor application in relation to the instant application. The Examiner is therefore advised that any such previous disclaimer and the cited references that it was made to avoid, may need to be revisited. Further, any disclaimer made in the instant application should not be read into or against the parent application or other related applications.

BACKGROUND

Various wireless access technologies have been proposed or implemented to enable mobile stations to perform communications with other mobile stations or with wired terminals coupled to wired networks. Examples of wireless access technologies include GSM (Global System for Mobile communications) and UMTS (Universal Mobile Telecommunications System) technologies, defined by the Third Generation Partnership Project (3GPP); and CDMA 2000 (Code Division Multiple Access 2000) technologies, defined by 3GPP2.

As part of the continuing evolution of wireless access technologies to improve spectral efficiency, to improve services, to lower costs, and so forth, new standards have been proposed. One such new standard is the Long Term Evolution (LTE) (also referred to as the Evolved Universal Terrestrial Radio Access (EUTRA) standard) from 3GPP, which seeks to enhance the UMTS technology.

In a wireless communications network, information is communicated wirelessly between mobile stations and base stations. In response to information received in the downlink (from base station to a mobile station), the mobile station can send acknowledgment information to either provide a positive acknowledge (ACK) of successful receipt of the data, or negative acknowledgment (NAK) to indicate that the data was not successfully received. To improve reliability, a recent development of LTE proposed use of ACK/NAK repetition, in which a mobile station repeats the sending of an ACK or NAK in response to downlink information from the base station, to improve the likelihood that the base station receives the ACK or NAK. This may be particularly

useful when the mobile station is in a region of a cell or cell sector that has relatively poor wireless conditions, such as at the edge of the cell or cell sector, or in another location associated with obstructions that may result in reduced signal strength or increased noise.

An issue associated with repetition of ACK/NAK is that in response to consecutively received pieces of downlink information, the acknowledgment information for such consecutively received pieces of information may collide, which may cause the base station to not reliably receive the acknowledgment information associated with the consecutively transmitted pieces of downlink information.

SUMMARY

In general, according to a preferred embodiment, a method of providing acknowledgment information by a first wireless device comprises the first wireless device sending repeated instances of acknowledgment information in respective first and second frame structures, in response to receipt of first information from a second wireless device. In addition, the first wireless device also sends further acknowledgment information in the second frame structure that is responsive to second information received from the second wireless device.

Other or alternative features will become apparent from the following description, from the drawings, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Some embodiments of the invention are described with respect to the following figures:

FIG. 1 is a block diagram of an example arrangement that includes a wireless communications network that incorporates some preferred embodiments of the invention;

FIGS. 2 and 3 illustrate the sending of downlink data and responsive repeated instances of acknowledgment information in accordance with some preferred embodiments; and

FIG. 4 is a flow diagram of a process of sending acknowledgment information, according to an embodiment.

DETAILED DESCRIPTION

In accordance with some preferred embodiments, a technique or mechanism is provided to allow for transmission of repeated instances of acknowledgment information while avoiding the issue of collisions in acknowledgment information sent in response to multiple pieces of received information. In some embodiments, the acknowledgment information is sent by a mobile station in the uplink (from the mobile station to the base station) in response to receipt of downlink data from the base station. The acknowledgment information includes either a positive acknowledgment (ACK) to indicate successful receipt of the data, or a negative acknowledgment (NAK) to indicate unsuccessful receipt of the data.

To improve reliability under certain conditions, the mobile station can be configured to perform ACK/NAK repetition, in which multiple instances of the ACK/NAK information is sent in response to receipt of a particular piece of downlink data. In some implementations, the number of ACK/NAK repetitions configured in the mobile station can be two. In other implementations, the mobile station can be configured to send three or four or more instances of the ACK/NAK information (number of ACK/NAK repetitions is three or four or more). ACK/NAK repetition is useful

when the mobile station is located in a region of a cell or cell sector that is associated with unreliable wireless signaling. For example, the mobile station may be located at the edge of the cell or cell sector, or the mobile station may be located in a region with obstructions that reduce signal strength or increase noise.

An issue associated with performing ACK/NAK repetition is the likelihood of collisions of ACK/NAK information when the mobile station sends respective repeated ACK/NAKs in response to consecutively received pieces of downlink data. In accordance with some embodiments, to eliminate or reduce the likelihood of collisions of ACK/NAK information, the repeated instance of an ACK/NAK may be communicated in a format that allows for multiple ACK/NAKs (that are responsive to different pieces of downlink data) to be transmitted together. Thus, this predefined format allows for the repeated ACK/NAK responsive to a first piece of data to be sent by the mobile station together with the first ACK/NAK responsive to a second piece of downlink data.

In some embodiments, the wireless communications network is according to the Long Term Evolution (LTE) standard from 3GPP (Third Generation Partnership Project), which is an enhancement of the UMTS (Universal Mobile Telecommunications System) wireless technology. The LTE standard is also referred to as the EUTRA (Evolved Universal Terrestrial Radio Access) standard. Reference to an LTE (or EUTRA) wireless communications network refers to the wireless communications network that conforms to the requirements of the LTE (or EUTRA) standard developed by 3GPP, as that standard currently exists or as the standard evolves over time. Note that LTE (or EUTRA) can refer to the current LTE (or EUTRA) standard, or to modifications of the LTE (or EUTRA) standard that are made over time. It is expected that in the future a standard that has evolved from LTE (or EUTRA) may be referred to by another name. It is contemplated that the term "LTE" or "EUTRA" as used herein is intended to cover such future standards as well. In alternative embodiments, wireless communications networks according to other standards can be employed.

Although reference has been made to transmitting repeated uplink ACK/NAKs in response to downlink data, it is noted that other preferred embodiments of the invention can be applied to scenarios in which a base station transmits a downlink ACK/NAKs in response to uplink data from the mobile station. Moreover, although reference is made to sending ACK/NAK in response to received data, it is noted that ACK/NAK can also be sent in response to control signaling.

FIG. 1 shows an example wireless network in which some embodiments of the invention can be provided. The wireless network includes a base station **100** that includes an antenna array or other antenna assembly **102** for sending wireless signals into a cell sector **108**. A cell sector is one section of a cell of a cellular network. In alternative implementations, element **108** can represent an entire cell. More generally, a "cell segment" refers to either a cell or a cell sector.

Although just one base station is depicted in FIG. 1, it is noted that a wireless network would typically include multiple base stations. In some embodiments, the wireless network is an LTE wireless network.

In an LTE wireless network, the base station **100** is an enhanced node B ("eNode B"), which includes a base transceiver station that includes the antenna array **102**. The base station **100** may also include a radio network controller that cooperates with the enhanced node B. The radio net-

work controller and/or enhanced node B can perform one or more of the following tasks: radio resource management, mobility management for managing mobility of mobile stations, routing of traffic, and so forth. Note that one radio network controller can access multiple eNode Bs, or alternatively, an eNode B can be accessed by more than one radio access controller.

More generally, the term "base station" can refer to a cellular network base station, an access point used in any type of wireless network, or any type of wireless transmitter to communicate with mobile stations.

As depicted in FIG. 1, the base station **100** includes one or more central processing units (CPUs) **122**, which is (are) connected to storage **124**. Moreover, the base station **100** includes software **126** that is executable on the CPU(s) **122** to perform tasks of the base station **100**.

The mobile station **110** of FIG. 1 also includes one or more CPUs **130** that are connected to storage **132**. The mobile station **110** also includes software **134** that is executable on the CPU(s) **130** to perform tasks of the mobile station **110**. In addition, the mobile station **110** includes an interface **131** to communicate wirelessly with the base station **100**.

The base station **100** is connected to a serving and/or packet data network (PDN) gateway **112**, which terminates the user plane interface toward the enhanced node B and assumes the responsibility for packet routing and transfer towards an external network **114**, which can be a packet data network such as the Internet or other types of network.

The arrangement depicted in FIG. 1 is provided for purposes of example. In other implementations, other wireless network arrangements are used.

In accordance with some embodiments, downlink data in an LTE wireless communications network is transmitted in PDSCH (physical downlink shared channel) subframes. The PDSCH is a traffic channel. In other implementations, the downlink data can be transmitted in other downlink traffic channels. An LTE subframe is a portion of an LTE frame. An LTE frame has a predefined overall time length that is divided into a predefined number of time slots. An LTE frame is made up of multiple subframes, where an LTE subframe can include some predefined number of the slots (e.g., two slots) of the LTE frame.

In response to receiving downlink data in a PDSCH subframe, the mobile station transmits acknowledgment information (ACK/NAK) to indicate successful or unsuccessful receipt of the downlink data in the PDSCH subframe. In some embodiments, the ACK/NAK is sent by the mobile station in the uplink direction in a PUCCH (physical uplink control channel) subframe. More generally, the repeated instances of ACK/NAK are sent in consecutive frame structures, where a "frame structure" can include a subframe or some other frame structure.

As noted above, ACK/NAK repetition can be enabled for at least one mobile station that the base station **100** is communicating with. If the mobile station is configured to perform ACK/NAK repetition by sending two repeated instances of the ACK/NAK, then the mobile station will respond to a downlink PDSCH subframe by sending two repeated instances of ACK/NAK in consecutive PUCCH subframes. For example, as shown in FIG. 2, in response to downlink data_1 received in PDSCH subframe n, a mobile station configured to perform ACK/NAK repetition will send two instances of ACK/NAK (each instance represented as ACK/NAK_1) in consecutive PUCCH subframes n+4 and n+5.

FIG. 2 also indicates that another piece of downlink data (data₂) is scheduled to be transmitted to the same mobile station in the next consecutive PDSCH subframe (n+1). Since the mobile station is configured to perform ACK/NAK repetition, the mobile station will send two repeated instances of ACK/NAK₂ in consecutive PUCCH subframes (n+5, n+6).

Note that in this example, one instance of ACK/NAK₁ and one instance of ACK/NAK₂ are scheduled to be transmitted in the same PUCCH subframe (n+5). If not properly handled, ACK/NAK₁ will collide with ACK/NAK₂ in PUCCH subframe n+5.

To address this issue, in accordance with some embodiments, ACK/NAK₁ and ACK/NAK₂ are transmitted together in PUCCH subframe n+5 using a predefined format that allows for communication of multiple different pieces of ACK/NAK information. In some embodiments, an ACK/NAK is communicated as a single bit, where the bit having a first value (e.g., "1") represents ACK, and the bit having a second value (e.g., "0") represents NAK. In such embodiments, sending two pieces of ACK/NAK information refers to sending two information bits in the PUCCH subframe (e.g., ACK/NAK₁ is sent in a first bit, while ACK/NAK₂ is sent in a second bit).

In one example implementation, the predefined format that allows for transmission of multiple different ACK/NAK bits in the same PUCCH subframe is referred to as format 1b. Format 1b differs from a different PUCCH format 1a, in which only a single ACK/NAK bit is allowed in the PUCCH subframe. In the example of FIG. 2, ACK/NAK₁ sent in PUCCH subframe n+4 is according to format 1a, and ACK/NAK₂ in PUCCH subframe n+6 is also according to format 1a. However, ACK/NAK₁ and ACK/NAK₂ in PUCCH subframe n+5 are sent together according to format 1 b. In one implementation, the two ACK/NAK bits are transmitted together using QPSK (quadrature phase-shift keying) modulation.

The ability to use different formats for communicating acknowledgment information allows for greater flexibility in performing ACK/NAK repetition, while avoiding or reducing the likelihood of ACK/NAK collisions.

FIG. 3 shows another example in which the ACK/NAK repetition is set at 3 (in other words three instances of ACK/NAK is sent by the mobile station in response to downlink data in a particular PDSCH subframe). When the ACK/NAK repetition is set at 3, data for the same mobile station cannot be sent in the downlink direction in more than two consecutive PDSCH subframes. Data for the same mobile station can be sent in two consecutive PDSCH subframes, followed by an intermediate subframe period that does not contain downlink data for the mobile station, then followed by another PDSCH subframe that contains data for the same mobile station. In the example of FIG. 3, data₁, data₂, and data₃ are sent in three different PDSCH subframes to the same mobile station. Data₁ is sent in PDSCH subframe n data₂ is sent in PDSCH subframe n+1, and data₃ is sent in PDSCH subframe n+3, where intermediate subframe n+2 (which does not contain downlink data for the mobile station) is provided to separate the transmission of data₂ and data₃. Downlink data can be scheduled to the same mobile station every two consecutive PDSCH subframes. However, after the two consecutive subframes, a separation subframe has to be provided before another PDSCH subframe can be sent to the same mobile station.

As further shown in FIG. 3, ACK/NAK₁ for data₁ is sent as three repeated instances in consecutive PUCCH

subframes n+4, n+5, and n+6. The three repeated instances of ACK/NAK₂ (responsive to data₂) are sent in PUCCH subframes n+5, n+6, and n+7. Note that PUCCH in subframe n+5 and n+6 each contains both ACK/NAK₁ and ACK/NAK₂. No data for the mobile station is sent in PDSCH subframe n+2, since doing so would require an ACK/NAK in PUCCH subframe n+6 which already is sending two other ACK/NAK bits. Thus, a separation PDSCH subframe is provided between data₂ and data₃, such that ACK/NAK₃ starts in PUCCH subframe n+7 rather than PUCCH subframe n+6.

FIG. 4 is a flow diagram of a process according to an embodiment that is performed at the mobile station 110, which is assumed to be configured to perform ACK/NAK repetition. First downlink data is received (at 402) in a downlink channel subframe, such as a PDSCH subframe. Second downlink data is received (at 404) in another PDSCH subframe, which can be consecutive to the PDSCH subframe containing the first downlink data. In response to the first and second downlink data, the mobile station prepares (at 406) the repeated instances of acknowledgment information responsive to the first and second downlink data. It is assumed that the mobile station is configured to send two repeated instances in response to each piece of downlink data.

The mobile station sends (at 408) the two repeated instances of acknowledgment information responsive to the first downlink data in first and second consecutive uplink control channel (e.g., PUCCH) subframes. The first uplink control channel is at some offset from the downlink subframe carrying the first downlink data. The mobile station sends repeated instances of the acknowledgment information responsive to the second downlink data in second and third consecutive uplink control channel subframes (at 410).

Although reference is made to the mobile station performing the process of FIG. 4, it is noted that the base station can also be configured to perform the process of FIG. 4, where the base station is to acknowledge receipt of uplink information data (and/or signaling) from a mobile station.

In an alternative embodiment, it is contemplated that the mobile station can use a scheduled PUSCH (physical uplink shared channel) to send a repeated instance of ACK/NAK. Thus, for example, referring back to FIG. 2, if a PUSCH is scheduled to be sent in subframe n+5, then the ACK/NAK₁ that was supposed to have been sent in PUCCH subframe n+5 can instead be sent in PUSCH subframe n+5. The second repeated ACK/NAK₁ instance can be multiplexed with data on the PUSCH, according to the LTE standard.

As yet another alternative, if a PUSCH transmission was scheduled for subframe n+5, this PUSCH transmission can be skipped to avoid collision with the ACK/NAK scheduled to be sent in PUCCH subframe n+5.

The ACK/NAK repetition of a given mobile station is configurable by the base station. For example, the base station can send a parameter to the mobile station to specify the number of repetitions (2, 3, 4, or more). The mobile station-specific ACK/NAK repetition parameter can be configured by using RRC (radio resource control) signaling or other type of control signaling.

Instructions of software described above (including software 126 and 130 of FIG. 1) are loaded for execution on a processor (such as one or more CPUs 122 and 130 in FIG. 1). The processor includes microprocessors, microcontrollers, processor modules or subsystems (including one or more microprocessors or microcontrollers), or other control

or computing devices. As used here, a “processor” can refer to a single component or to plural components (e.g., one CPU or multiple CPUs).

Data and instructions (of the software) are stored in respective storage devices, which are implemented as one or more computer-readable or computer-usable storage media. The storage media include different forms of memory including semiconductor memory devices such as dynamic or static random access memories (DRAMs or SRAMs), erasable and programmable read-only memories (EPROMs), electrically erasable and programmable read-only memories (EEPROMs) and flash memories; magnetic disks such as fixed, floppy and removable disks; other magnetic media including tape; and optical media such as compact disks (CDs) or digital video disks (DVDs). Note that the instructions of the software discussed above can be provided on one computer-readable or computer-usable storage medium, or alternatively, can be provided on multiple computer-readable or computer-usable storage media distributed in a large system having possibly plural nodes. Such computer-readable or computer-usable storage medium or media is (are) considered to be part of an article (or article of manufacture). An article or article of manufacture can refer to any manufactured single component or multiple components.

In the foregoing description, numerous details are set forth to provide an understanding of the present invention. However, it will be understood by those skilled in the art that the present invention may be practiced without these details. While the invention has been disclosed with respect to a limited number of embodiments, those skilled in the art will appreciate numerous modifications and variations therefrom. It is intended that the appended claims cover such modifications and variations as fall within the true spirit and scope of the invention.

What is claimed is:

1. An apparatus comprising:

a memory; and

at least one processing unit in communication with the memory, wherein the at least one processing unit and memory are configured to:

determine an occurrence of a semi-persistently scheduled transmission on an uplink traffic channel in a first uplink subframe, wherein acknowledgement information is multiplexed on the uplink traffic channel in absence of a transmission of a repetition of acknowledgement information;

receive a configuration for acknowledgment information transmission repetition, wherein the configuration includes a value for a number of transmission repetitions for acknowledgement information, and wherein acknowledgement information corresponding to downlink transmissions is to be repeated on consecutive uplink subframes according to the configuration;

receive first and second scheduled transmissions from a second wireless device on respective first and second downlink (DL) subframes;

prepare acknowledgement information for the first and second scheduled transmissions based on the configuration for acknowledgment information transmission repetition;

transmit, using an uplink (UL) control channel different from an UL uplink traffic channel, the acknowledgement information for the first scheduled transmission together with the acknowledgement information for the second scheduled transmission in a first uplink

subframe in a single message, wherein the first uplink subframe is subsequent to receiving the first and second scheduled transmissions; and

skip transmission of the semi-persistently scheduled transmission on the uplink traffic channel in the first uplink subframe based determining the semi-persistently scheduled transmission would collide with ongoing repetitions of acknowledgement information for both of the first and second scheduled transmissions.

2. The apparatus of claim 1,

wherein the at least one processing unit and memory are further configured to determine transmission of acknowledgement information for any further downlink transmissions cannot occur while the transmission of acknowledgement information for any further downlink transmissions would collide with ongoing repetitions of acknowledgement information for both of the first and second scheduled transmissions.

3. The apparatus of claim 2,

wherein to determine that transmission of acknowledgement information for any further downlink transmissions cannot occur, the at least one processing unit and memory are further configured to:

determine a downlink transmission will not be scheduled in a third consecutive DL subframe.

4. The apparatus of claim 1,

wherein the at least one processing unit and memory are further configured to transmit a repetition of the acknowledgement information for the first scheduled transmission together with the acknowledgement information for the second scheduled transmission in a second UL subframe in a single message.

5. The apparatus of claim 1,

wherein the at least one processing unit and memory are further configured to:

determine repetitions of acknowledgement information for at least one of the first and second scheduled transmissions will not occur in a third uplink subframe; and

determine transmission of acknowledgement information for downlink transmission in a third DL subframe can occur wherein a corresponding acknowledgement information transmission will occur in the third uplink subframe.

6. The apparatus of claim 1,

wherein, to transmit the acknowledgement information for the first scheduled transmission together with the acknowledgement information for the second scheduled transmission, the at least one processing unit and memory are further configured to:

transmit at least one bit indicating positive acknowledgement or negative acknowledgement.

7. The apparatus of claim 1,

wherein the first and second DL subframes are consecutive DL subframes.

8. The apparatus of claim 1,

wherein the configuration is received in a radio resource control message and specifies a wireless device-specific number of repetitions of acknowledgement information.

9. A wireless device comprising:

an interface; and

a processor coupled to the interface, wherein the interface and the processor are configured to:

determine an occurrence of a semi-persistently scheduled transmission on an uplink traffic channel in a

first uplink frame structure, wherein acknowledgement information is multiplexed on the uplink traffic channel in absence of a transmission of a repetition of acknowledgement information;

receive a configuration for acknowledgment information transmission repetition, wherein the configuration includes a value for a number of transmission repetitions for acknowledgement information, and wherein acknowledgement information corresponding to downlink transmissions is to be repeated on consecutive uplink frame structures according to the configuration;

receive first and second scheduled transmissions from a second wireless device on respective first and second downlink (DL) frame structures,

prepare acknowledgement information for the first and second scheduled transmissions based on the configuration for acknowledgment information transmission repetition;

transmit, using an uplink (UL) control channel different from an UL uplink traffic channel, the acknowledgement information for the first scheduled transmission together with the acknowledgement information for the second scheduled transmission in a first uplink frame structure in a single message, wherein the first uplink frame structure is subsequent to receiving the first and second scheduled transmissions; and

skip transmission of the semi-persistently scheduled transmission on the uplink traffic channel in the first uplink frame structure based determining the semi-persistently scheduled transmission would collide with a transmission of repetition of acknowledgement information for both of the first and second scheduled transmissions.

10. The wireless device of claim 9, wherein the interface and the processor are further configured to determine transmission of acknowledgement information for any further downlink transmissions cannot occur while the transmission of acknowledgement information for any further downlink transmissions would collide with a transmission of a repetition of acknowledgement information for both of the first and second scheduled transmissions.

11. The wireless device of claim 10, wherein to determine that transmission of acknowledgement information for any further downlink transmissions cannot occur, the processor and interface are further configured to:

determine a downlink transmission will not be scheduled in a third consecutive DL frame structure.

12. The wireless device of claim 9, wherein the processor and interface are further configured to transmit a repetition of the acknowledgement information for the first scheduled transmission together with the acknowledgement information for the second scheduled transmission in a second UL frame structure in a single message.

13. The wireless device of claim 9, wherein the processor and interface are further configured to:

determine repetitions of acknowledgement information for at least one of the first and second scheduled transmissions will not occur in a third uplink frame structure; and

determine transmission of acknowledgement information for downlink transmission in a third DL frame structure

can occur wherein a corresponding acknowledgement information transmission will occur in the third uplink frame structure.

14. The wireless device of claim 9, wherein, to transmit the acknowledgement information for the first scheduled transmission together with the acknowledgement information for the second scheduled transmission, the interface and the processor are further configured to:

transmit at least one bit indicating positive acknowledgement or negative acknowledgement.

15. A non-transitory memory medium storing program instructions executable by a processor of a wireless device to:

determine an occurrence of a semi-persistently scheduled transmission on an uplink traffic channel in a first uplink frame structure, wherein acknowledgement information is multiplexed on the uplink traffic channel in absence of a transmission of a repetition of acknowledgement information;

receive a configuration for acknowledgment information transmission repetition, wherein the configuration includes a value for a number of transmission repetitions for acknowledgement information, and wherein acknowledgement information corresponding to downlink transmissions is to be repeated on consecutive uplink frame structures according to the configuration;

receive first and second scheduled transmissions from a second wireless device on respective first and second downlink (DL) frame structures;

prepare acknowledgement information for the first and second scheduled transmissions based on the configuration for acknowledgment information transmission repetition;

transmit, using an uplink (UL) control channel different from an UL uplink traffic channel, the acknowledgement information for the first scheduled transmission together with the acknowledgement information for the second scheduled transmission in a first uplink frame structure in a single message, wherein the first uplink frame structure is subsequent to receiving the first and second scheduled transmissions; and

skip transmission of the semi-persistently scheduled transmission on the uplink traffic channel in the first uplink frame structure based determining the semi-persistently scheduled transmission would collide with a transmission of a repetition of acknowledgement information for both of the first and second scheduled transmissions.

16. The non-transitory memory medium of claim 15, wherein the program instructions are further executable to determine transmission of acknowledgement information for any further downlink transmissions cannot occur while the transmission of acknowledgement information for any further downlink transmissions would collide with a transmission of a repetition of acknowledgement information for both of the first and second scheduled transmissions.

17. The non-transitory memory medium of claim 16, wherein to determine that transmission of acknowledgement information for any further downlink transmissions cannot occur, the program instructions are further executable to:

determine a downlink transmission will not be scheduled in a third consecutive DL frame structure.

18. The non-transitory memory medium of claim 15, wherein the program instructions are further executable to transmit a repetition of the acknowledgement information for the first scheduled transmission together with the acknowledgement information for the second scheduled transmission in a second UL frame structure in a single message. 5

19. The non-transitory memory medium of claim 15, wherein the program instructions are further executable to: 10

determine repetitions of acknowledgement information for at least one of the first and second scheduled transmissions will not occur in a second uplink frame structure; and

determine transmission of acknowledgement information for downlink transmission in a third DL frame structure can occur wherein a corresponding acknowledgement information transmission will occur in a third uplink frame structure. 15

20. The non-transitory memory medium of claim 15, wherein, to transmit the acknowledgement information for the first scheduled transmission together with the acknowledgement information for the second scheduled transmission, the program instructions are further executable to: 20

transmit at least one bit indicating positive acknowledgement or negative acknowledgement. 25

21. The non-transitory memory medium of claim 15, wherein the first and second DL frame structures are consecutive DL frame structures. 30

* * * * *